Evaluation of Undisturbed Sampling Techniques for Pumiceous Soils

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Volcanic Soils

Soils containing pumice or volcanic ash are found across much of the North Island. In some cases, these soils are encountered in their original depositional state while in others they have been transported and redeposited in an alluvial environment.

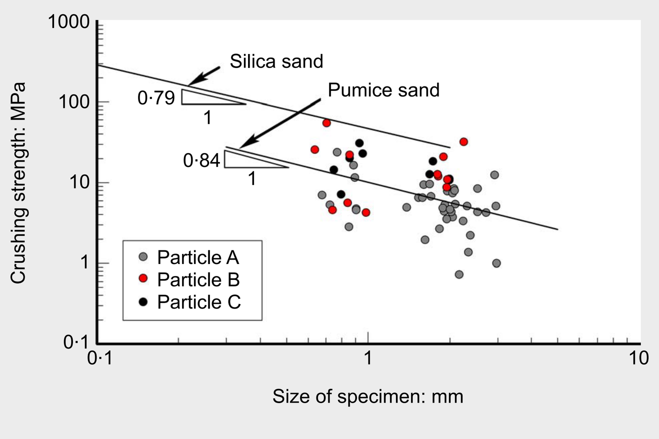

Figure 1: Crushing strength of Pumice and Silica sands (Orense et al. 2013)

The engineering behaviour of soil containing pumice may be significantly affected by three key characteristic properties of pumice:

- High crushability
- Low unit weight
- Presence of voids on the grain surfaces

Implications of High Crushability

Important in-situ properties or soil behaviours (including cyclic resistance) are often estimated from simple field tests using correlations that have typically been developed for hard-grained soils (i.e. quartz).

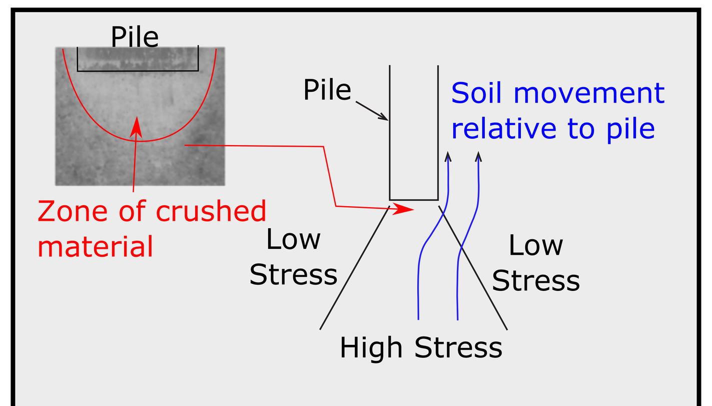

Figure 2: Soil streamlines around penetrating pile (modified from White & Bolton 2004)

Experiments show that some crushing occurs below the end of an advancing pile (figure 2) or CPT cone, even for quartz sands and other hard-grained soils

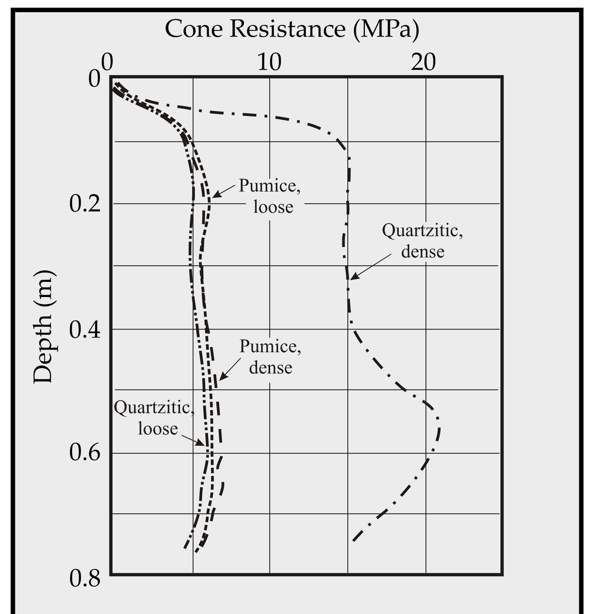

Figure 3: Cone resistance in Pumice and Silica sands (Wesley et al. 1999)

For hard-grained materials, cone resistance provides a good basis for estimating relative density. However, calibration chamber tests with pure pumice (Figure 3) show that relative density is insensitive to the same parameter because the penetration mechanism of the CPT is completely **dominated by crushing** of soil grains.

As a consequence, empirical correlations based on quartz sands are **inappropriate for pumice soils.**

Engineering properties can be determined directly in the laboratory from high quality field samples, but the success of undisturbed sampling is highly dependent on the type of soil and the selection of an appropriate sampler.

Aims

- **Establish if relatively undisturbed samples of pumiceous soil can be collected using "Advanced Soil Samplers".**
- **Provide guidance for sampling pumiceous soil.**

Soil Disturbance

Conventional samplers have been found to be ineffective for sampling coarse (cohesionless) materials such as sands due to the **disturbance** which occurs during sampling (Figure 4).

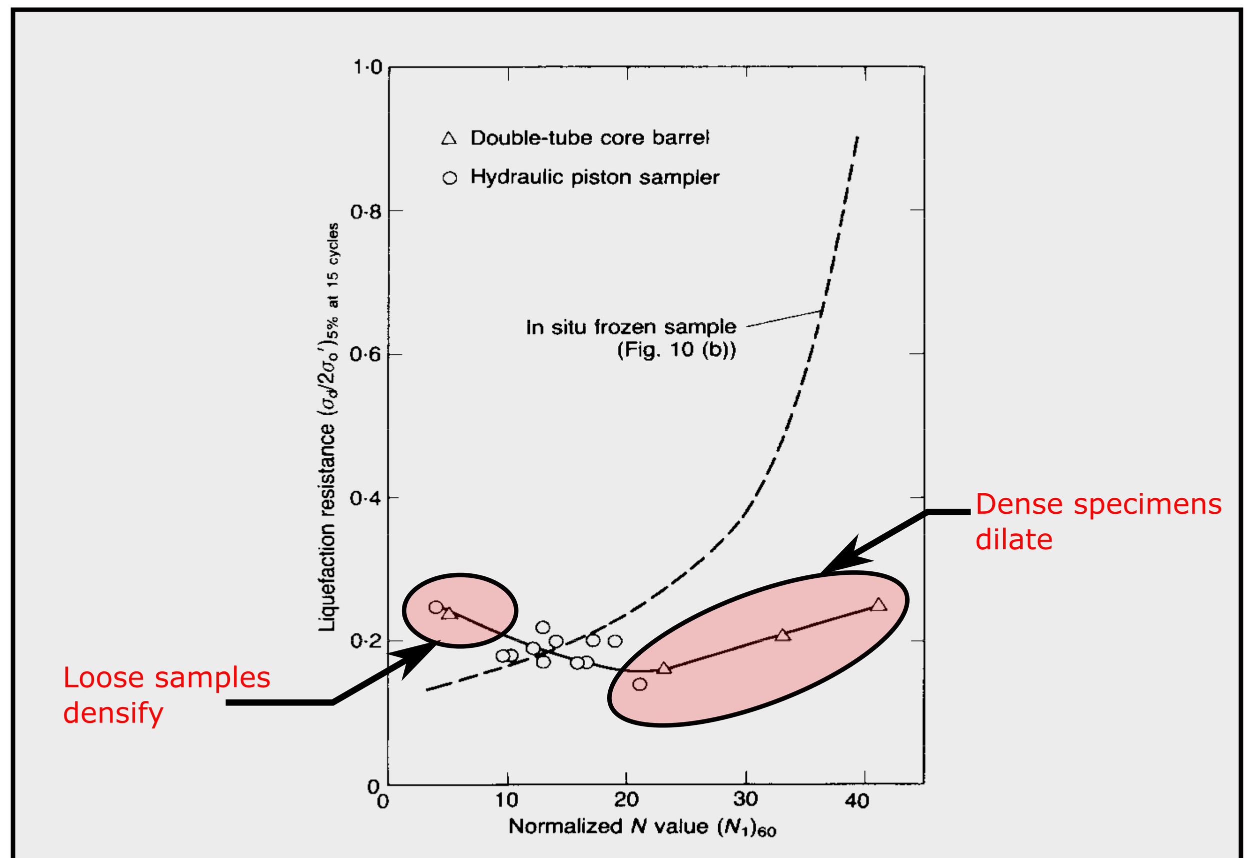

Figure 4: Cyclic resistance of tube and frozen sand samples (Yoshimi et al. 1994)

Sources of disturbance during sampling:

- **Sidewall friction** as sample enters sample barrel.
- **Shear stresses in the soil** as the sampler advances into the ground.

Unintentional disturbance can also occur after sampling during transport (vibration) & laboratory preparation (shearing).

Site Selection

Eight potential sites for sampling have been examined in Hamilton & Rangitaiki Plains.

Based on undisturbed sampling in Christchurch:

- GP-S sampling was successful in silty sands, with modest penetration resistance.
- Best D&M performance achieved in silts & clays.
- Hard gravels can damage GP-S cutting shoe and D&M sampling barrels.

To find the site with the greatest potential for successful sampling, borehole logs were analysed to determine:

- Depth and thickness of intervals containing pumice soils.
- Gradation of pumice materials.
- SPT penetration resistance of soil profile.

Location of Borehole 09 has preliminarily been chosen for undisturbed sampling:

- Soil layers with pumice material are relatively thick, homogeneous and shallow.
- Penetration resistances are near the upper limit for gel-push fixed piston (GP-S) sampling, but should also be large enough to be suitable for rotary (GP-Tr) sampling.
- Target soils have some silt content and very little gravel, making them accessible for the samplers being trialled (D&M, GP-S, GP-Tr and conventional push-tube)

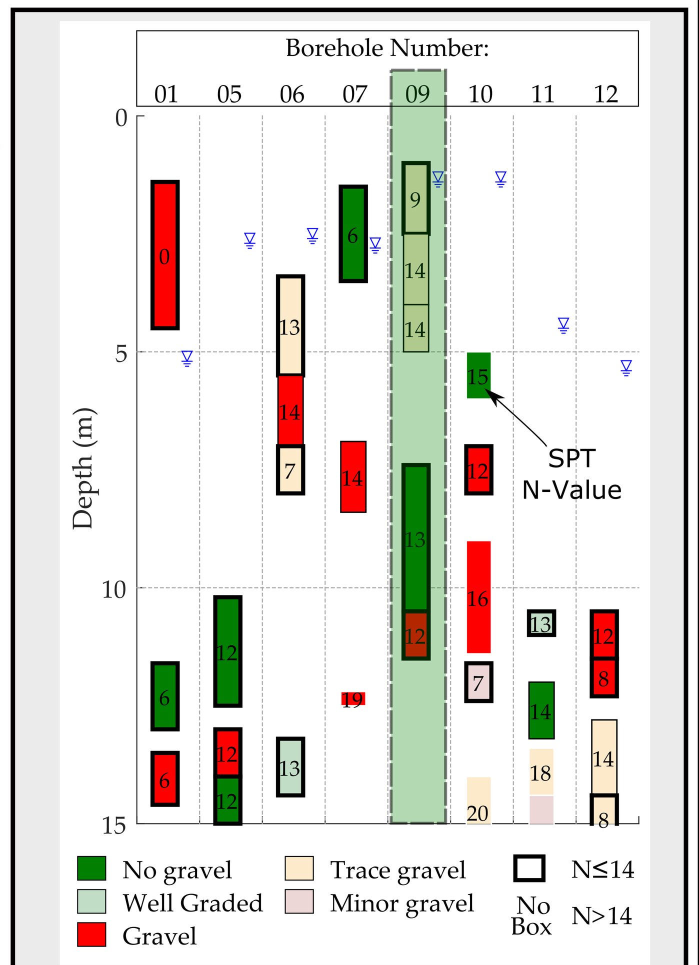

Figure 8: Intervals of soil containing pumice at prospective sampling sites

References

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Wesley, L., Meyer, V., Pranyoto, S., Pender, M., Larkin, T. & Duske, G. (1999) Engineering properties of a pumice sand. *Proc. 8th ANZ Conf. Geomechanics*.

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Yoshimi, Y., Tokimatsu, K. & Ohara, J. (1994) In situ liquefaction resistance of clean sands over a wide density range. *Geotechnique*. **44**(3):479-494

Advanced Soil Samplers

Dames & Moore Hydraulic Fixed Piston Sampler

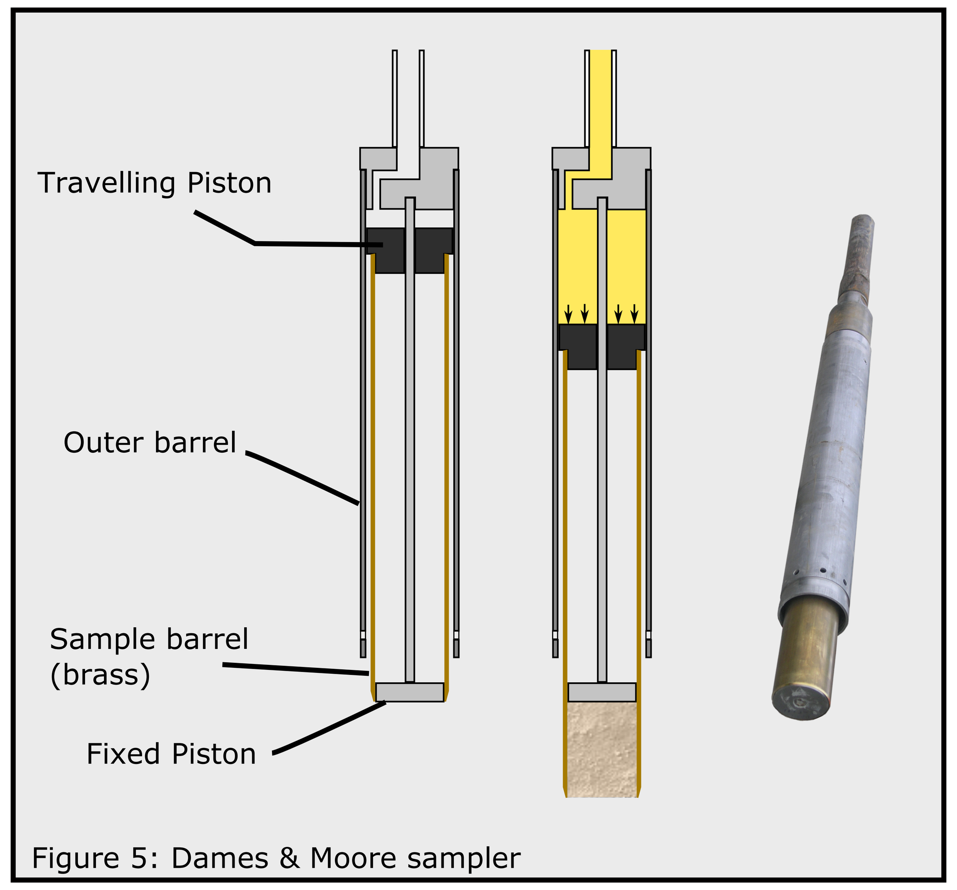

Figure 5: Dames & Moore sampler

- Magnitude of sidewall shear stresses acting on the sample during sampling and extrusion are reduced by using a **shorter sample barrel** (0.5m long).
- The use of brass sample barrels reduces the **interface friction angle** between the soil and sample barrel.
- The use of a **thin-walled** sample barrel reduces the deviatoric shear stress in the soil ahead of the sampler.

Gel-Push Fixed Piston & Rotary Sampler

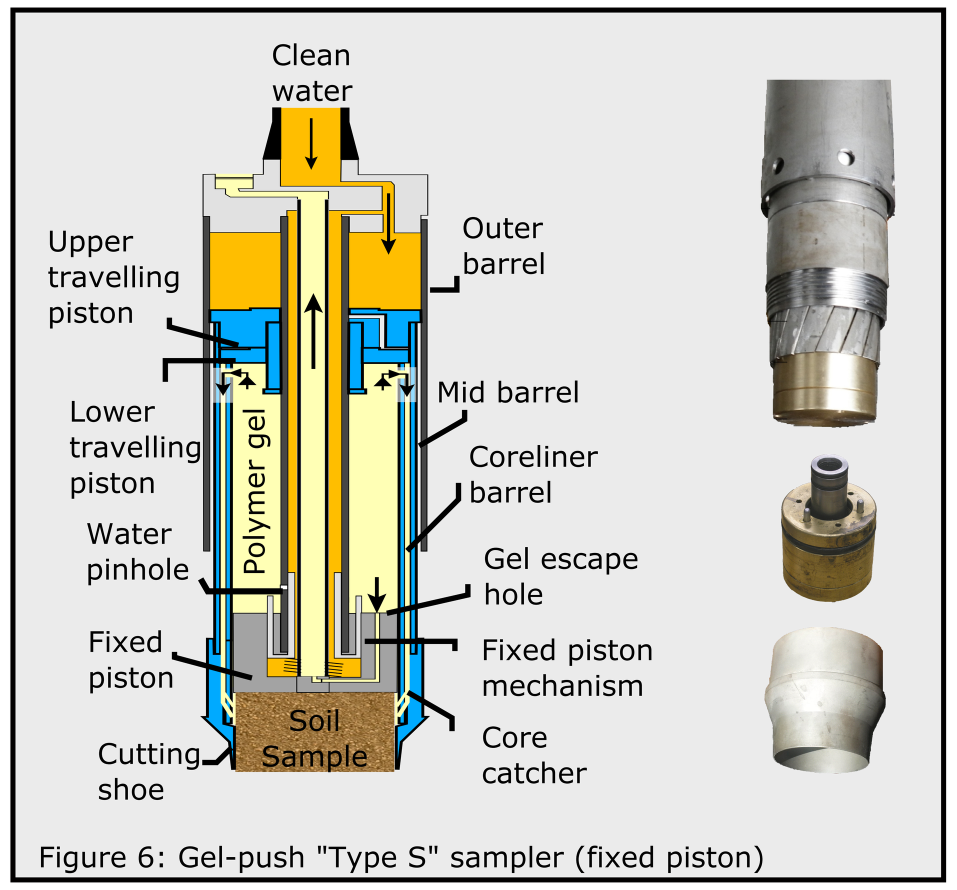

Figure 6: Gel-push "Type S" sampler (fixed piston)

- Gel-push sampling was developed in Japan as an **economical method** for obtaining undisturbed samples of silty and clean sands.
- The samplers are based on existing tools, which are modified so that a soil sample is coated with a **lubricating polymer gel** at the point of entry into the sampler.

Figure 7: Lubricating gel covering the soil sample

- A core catcher is activated to prevent the soil sample from falling out of the tool during recovery from the borehole.
- Soil samples are approximately **1m** in length.
- While the gel-push method eliminates the sidewall friction acting on the sample, it is **unable to provide lateral confinement** to the sample. Hence it is difficult to obtain samples of clean sands.
- Fixed piston tool recommended for deposits with low penetration resistance (qc ≤ 5 MPa or SPT N value < 15). Rotary sampler is suitable for suitable for stiffer soils.

Upcoming Field & Laboratory Work

The undisturbed sampling at the chosen location will take place between September and early October.

Samples from similar depths will be taken with each advanced sampler (GP-S, GP-Tr, D&M) and a conventional push-tube.

At the time of sampling, some samples will be extruded on site for a visual assessment of the quality which has been achieved.

The remaining samples will be transported to the Universities of Auckland and Canterbury for triaxial testing.

Additional in-depth site characterisation will be carried out by Liam Wotherspoon to provide profiles of shear wave velocities at the location of sampling. Once complete, the results from the laboratory testing will be evaluated against the field data to provide additional perspectives on the quality of the soil samples which were obtained.